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ABSTRACT

The Mathematics subtest of the Peabody Individual Achievement Test is analyzed and its content represented in a format similar to that used in diagnostic math tests. An error analysis matrix is provided and its use is illustrated with application to the mathematics performance of a sixth grade child. The subtest is recommended as a diagnostic test to identify specific strengths and weaknesses in mathematics skill development. (CL)

University of Minnesota

Research Report No. 5

DIAGNOSTIC TESTING IN MATHEMATICS: AN EXTENSION OF THE PIAT?

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IRLD

Institute for Research on Learning Disabilities

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V. Ethological Research on Placement Team Decision Making

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VII. Reliability and Validity of Formative Evaluation Procedures

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March 1979

Abstract

Diagnostic testing in mathematics involves identification of specific strengths and weaknesses in mathematics skill development. While the practicum greatly enhances assessment practices and educational planning activities, few diagnostic math tests are available. The Mathematics subtest of the Peabody Individual Achievement Test was analyzed and its content represented in a format similar to that used in diagnostic math tests. An error analysis matrix is provided and its use is illustrated with application to the mathematics performance of a sixth grade eleven year old child. A brief interpretation and discussion section are presented.

Diagnostic Testing in Mathematics: An Extension of the PIAT?

Diagnostic testing in mathematics involves identification of specific strengths and weaknesses in mathematics skill development as a basis for subsequent remedial programming. While the assessment of mathematical skills is relatively clear-cut, there are few diagnostic math tests available (Salvia & Ysseldyke, 1978).

The Key Math Diagnostic Arithmetic Test (Connolly, Nachtmann, & Pritchett, 1971) is an individually administered test of mathematics skill development. It provides four measures of achievement: grade equivalent total test performance, as well as area, subtest, and item performances. The 209 items are organized into 14 subtests within three general areas (i.e., content, operations, and applications). While the Key Math can be used as a norm-referenced or criterion-referenced test, its real value is in its use as a criterion-referenced measure (Salvia & Ysseldyke, 1978). This simply means that one analyzes a child's performance relative to the specific areas, subtests, and/or items that the child answered correctly and incorrectly. It is assumed that such a procedure will enable patterns of skill development to be ascertained and remedial programming attempts to be facilitated.

The mathematics subtest of the Peabody Individual Achievement Test (PIAT) is a set of 84 questions designed to assess various levels of arithmetic performance (Dunn & Markwardt, 1970). Age and grade equivalents and percentile and standard scores are available measures of achievement from the PIAT for school-age children. The

reliability and validity of the PIAT mathematics subtest have been investigated and reported to be adequate (Dunn & Markwardt, 1970; Salvia & Ysseldyke, 1978); the content validitiy was based on "extensive reviews of curriculum materials used at each grade level" (Dunn & Markwardt, 1970, p. 50). The format of the test is multiple-choice identification in which the child chooses the correct response to a question from four pictorially presented choices. The items are arranged in order of difficulty with easier items occurring in the initial portion of the test. A basal and ceiling procedure is utilized to establish the appropriate items for a particular child.

While the PIAT may be useful for one purpose of educational assessment (i.e., screening or placement), one tends to find it inadequate with regard to a second purpose (i.e., educational planning); that is, the utility of the mathematics subtest as a diagnostic test has not been demonstrated. However, the problem is not with the content of the items but more with the format of score representation. It is difficult to translate age or grade equivalent scores into meaningful instructional objectives based on the summary information reported by the PIAT. What specifically does one teach a child who obtains a 3.2 on the mathematics subtest?

An analysis of the items of the PIAT mathematics subtest indicates that 14 subgroups of behavioral activities within three main subsections of mathematical abilities can be represented. The proposed subgroups within the PIAT mathematics subtest, grouped according to the three major areas of abilities, are reported in Table 1.

Insert Table 1 about here

The first subsection (foundations) is comprised of subgroups of items which deal with match-to-sample number identification, sizes of quantities, identification of shapes, and knowledge about general mathematical concepts (e.g., days in week and year). In general, these items occur in the earlier (i.e., for younger children) portions of the total subtest. A description of the behavioral activities within the Foundations subsection is presented in Table 2. The subgroup classifications, PIAT item numbers, and statements of each behavioral activity are included; within the behavioral activities, specific words and content from the items are indicated in parentheses.

Insert Table 2 about here

The items within the Basic Facts subsection deal with combining and subtracting sets, identifying monetary values, and recognizing and using the mathematical operations of multiplication and division. A description of the items in this subsection is contained in Table 3. These items are generally presented within the middle section of the total mathematics subtest.

Insert Table 3 about here

A description of the items in the Applications subsection is contained in Table 4. The subgroups of items within this area deal with identifying and using fractions, supplying missing parts through

equations, solving verbally presented word problems involving several operations, identifying and using geometric formulae, and using algebraic equations. The items are generally contained in the later sections of the PIAT mathematics subtest.

Insert Table 4 about here

Given this information, one can begin to use the PIAT mathematics subtest within a diagnostic testing framework; that is, it can be used to identify specific strengths and weaknesses within areas, subgroups, and items in a procedure similar to that of the Key Math.

The wide range of content coverage does not facilitate this process; in fact, basal and ceiling procedures may be such that only a narrow range of content is sampled. In this event, items within a subgroup (e.g., 7, 9, 10, 23, 26) may not be completely sampled. However, error analysis within and between the subgroups may provide meaningful information for educational planning beyond that provided by global scores. To facilitate this process, an error analysis matrix has been developed and is presented in Table 5. It is organized into three subsections and contains PIAT item numbers arranged by subgroups within the main areas of content sampled by the subtest.

Insert Table 5 about here

To use the matrix, one merely underlines items which were sampled within a subgroup, circles correct ones and crosses out incorrect ones; patterns of performance within the subtest can then be analyzed.

Percentages of correct and incorrect items within subsections and subgroups can be computed by dividing the total items sampled (underlined items within subsection and/or subgroup) into the number of correct (circled) or incorrect items (crossed out).

An example of the use of this matrix in the analysis of the mathematics performance of a sixth grade eleven year old child (Charles) is presented in Table 6. In following the scoring procedures suggested in the test manual, Charles' performance (relative to others in his grade) would be recorded as the following: raw score 45; grade equivalent 5.3; percentile 33; standard score 95. The performance would be interpreted as slightly below grade level expectancy and similar to or above approximately 33 percent of sixth grade children on whom the test was normed. Educational planning from this information is somewhat limited.

Insert Table 6 about here

Perusal of the additional information provided by the error analysis matrix (see Table 6) indicated that while Charles performed more than half of the items he attempted (i.e., 17/29), his performance was somewhat unevenly distributed according to the general subsections. Most of those items attempted (i.e., 80%) within the Foundations area were answered correctly. Of the 73 percent correctly answered in the Basic Facts subsection, 50 percent were in the Money subgroup, 75 percent were in the Multiplication subgroup, and 80 percent were in the Division subgroup. Individual item analysis indicates that Charles

was unable to recombine multiple units of four coin values (i.e., penny, nickel, dime, quarter) and identify which total was of greatest value, identify a thousand times 50, or identify how many hundreds are in a thousand.

In analyzing the 62 percent incorrect responses in the Applications subsection, it is apparent that Charles was unable to complete any items involving fractions, geometry or algebra; he correctly answered 60 percent of the questions presented in the subgroup of Numerical Relationships, and 50 percent within the subgroup of Word Problems. Those items which were incorrectly answered dealt with identification of place values (items 51 and 54), and completion of two step word problems (items 49 and 58).

These results suggest that Charles may be having trouble with place value (items 46, 38, 51, 54), with two-step problem solving (items 42, 49, 58), and with beginning division using place value. Additional informal assessment would be warranted to determine the exact nature of the skills Charles has acquired in these areas. Since all tests are merely samples of behavior, it is generally recommended to attempt to verify suggestive test performance with follow-up assessments. The results of such a procedure can help to clearly delimit areas in which instruction can be useful.

That the use of the error analysis matrix provides more information than merely reporting general achievement levels (e.g., 5.3) should be obvious; however, it by no measure defines disabilities or unequivocally identifies problem ares. When a child performs poorly on a test item, several explanations are possible. First, the

child may not have developed the skill being tested; that is, the test performance is a valid indication of a problem. It is also possible, however, that the test performance incorrectly identifies a problem area (i.e., false positive error). This may occur for a variety of reasons. For example, the nature of the behaviors sampled by the particular test may not match the way an individual child best handles information or performance (Salvia & Ysseldyke, 1978); the PIAT mathematics subtest required multiple-choice identifications without pencil or paper assistance. It may be that some children can perform PIAT items given different response options.

It is also possible that chance errors have occurred within a subgroup of items. The child may have lapsed in his or her attention to the task, may have misunderstood the item, and/or may have applied an inappropriate model (e.g., addition for subtraction) to the item. In analyzing PIAT subgroup error matrices, one of several error patterns is likely. The child may progress with incorrect followed by correct; progress with correct and incorrect, apparently randomly; or progress with only correct or incorrect within the range of items sampled. It is the responsibility of the teacher/diagnostician to attempt to analyze patterns of errors and to develop tentative hypotheses with regard to strengths and weaknesses. These hypotheses can then be verified with subsequent informal assessment.

Poor test performance may also result from the child not having been exposed to similar formal and informal experiences to those children on whom the test was normed. Salvia and Ysseldyke (1978) refer to this as "acculturation" and suggest that the interaction between

acculturation and actual behaviors sampled by tests may result in tests measuring different things for different children. Poor test performance may only be relative to the particular group to which an individual's performance is compared (e.g., the 110 sixth grade males in the PIAT standardization sample).

It should be evident that there are problems involved in testing children. Regardless of this issue, the use of a diagnostic testing approach to the PIAT mathematics subtest, within the range of the behaviors sampled, provides more information from which to begin to plan meaningful educational programs than simply recording global performance scores.

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Footnote

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Table 1

Subgroups of PIAT Mathematics Subtest

1. Foundations	2. Basic Facts	3. Applications
1.1 Number Discrimination	2.1 Addition	3.1 Fractions
1.2 Size Discrimination	2.2 Subtraction	3.2 Numerical Relationships
1.3 Shape Discrimination	2.3 Money	3.3 Word Problems
1.4 General Information	2.4 Multiplication	3.4 Geometry
	2.5 Division	3.5 Algebra

Table 2

Behavioral Activities Within Foundations (1) Subsection of PIAT Mathematics Subtest

Subgroup	PIAT Item	Behavioral Activity
1.1 Number Discrimination	1	given a numeral, the child finds one like it in a set of four choices (find, down, like).
	2	given a numeral, the child finds one like it in a set of four choices (find, down, like).
	3	given a numeral, the child finds one like it in a set of mathematical symbols (find, down, like).
	4	given a numeral, the child finds one like it in a set of numbers (find, like, down).
	12	given four two-digit numbers, the child will identify the one requested (number, 28).
	15	given a set of pictures, the child demonstrates awareness of the concept of the smallest quantity in a set (birthday cake, youngest child).
	17	given a set of numbers, the child can identify the one that comes just before ten (numbers, just before).
	25	given a set of numbers, the child can identify the one that comes just before 100 (numbers, just before, 100).
	33	given a set of two digit numbers, the child can identify what number is halfway between sixteen and twenty (series, numbers, left out, halfway between, sixteen, twenty).
1.2 Size Discrimination	5	given a picture of four circles in different sizes, the child can identify the biggest one (shapes, biggest).
	6	given a picture of four pencils in different sizes, the child can identify the shortest one (pencils, shortest).
1.3 Shape Discrimination	11	given four geometrical configurations, the child can identify the curved line (curved line).
	22	given four geometrical configurations, the child can identify a double circle (circles, double circle).
	41	given four geometrical shapes, the child can identify the one that is <u>not</u> a triangle (shapes, not, triangle).
1.4 General Information	19	given four choices, the child can identify how many days there are in one week (days, how many, one week).
	21	given pictures of four clocks, the child can identify correct time on hour distinction (four, clocks, eight o'clock).
	28	given four clock symbols, the child can identify one showing twenty minutes after ten (clock, twenty, minutes, after, ten, ten-twenty).
	35	given four choices, the child can identify how many days there are in a year (how many, days, year).
	40	given four choices, the child can identify how many inches are in a yard (how many, inches, yard).
	53	given pictures of thermometers showing four temperatures, the child can identify the coldest temperature (thermometer reading, coldest, temperature).
	69	given a Roman numeral, the child can identify the Arabic numeral equivalent from four choices (volume, series of books, marked, XLVI, Roman numerals, Arabic numerals).

Table 1

Behavioral Activities Within Basic Facts (2) Subsection of PIAT Mathematics Subtest

Subgroup	PIAT Item #	Behavioral Activity
2.1 Counting and Addition	7	given two sets of objects, the child identifies the sum of their elements (two, grandmother, number, how many, altogether).
	9	given a set of objects, the child identifies a second set with the same number of elements (dogs, cats, count, altogether, circles, equal, number, down, how many, same, group, set).
	10	given a set of objects, the child identifies the numeral that describes the number of elements in the set (row, circles, count, how many, altogether, number).
	23	given a set of numbers, the child indicates the quantity of three pairs (each, pair, shoes, how many, altogether).
	26	given a two digit dollar value and a one digit dollar value, the child can add and identify the result (how much, twelve, nine, dollars, altogether).
2.2 Subtraction	8	given a set of three, the child subtracts two elements and identifies result (three, puppies, gave away, how many, have left, number, had left).
	14	given the number five, the child subtracts three and identifies the result (five, pennies, spent, three, number, had left).
	24	given the number twelve, the child subtracts five and identifies result (storekeeper, twelve, pineapples, sold, five, number, had left).
	27	given the number nine, the child subtracts six and identifies result (nine, years old, how many, years older, than).
2.3 Money	16	given a set of four numeral choices, the child can identify which is equivalent to how many pennies are equal to a nickel (pennies, same, nickel).
	18	given a set of four number choices and the numbers 10, 5, and 1, the child can identify which is equivalent to how many pennies equal a dime, a nickel, and a penny (dime, nickel, penny, how many, be worth, altogether).
	29	given a set of four number choices, the child can identify the one equivalent to how many nickels equal forty cents (how many, nickels, equal, forty, cents).
	42	given four coin values of the monetary system, the child can recombine multiple units of those values and identify which is of greatest value (most, money, penny, nickel, dime, quarter, 12, 3, 70, 8).
	43	given a set of four dollar and cents values, the child can find the sum or product of six quarters (newsboy, collected, quarter, each, Sunday paper, sold, six, papers, how much, collect, altogether).

Table 3 (continued)

Subgroup	PIAT Item #	Behavioral Activity
2.4 Multiplication	30	given a mathematical statement with a missing operation sign, the child can identify, from four choices, the sign which makes the statement correct (sign, true).
	34	given a one digit number, the child multiplies by another one digit number and completes the product (six, five, pennies, how many, altogether).
	36	given a set of seven, the child multiplies by five and identifies result (seven, rows, desks, classroom, each, five, how many, altogether).
	46	given a set of number choices, the child can identify a thousand times 50 (number, represents, thousand, times, 50).
2.5 Division	31	given four sets of symbols, the child can find one which can be divided into two equal subsets (four, groups/sets, crosses, divided, two, exactly, same, number, each).
	32	given a set of twelve, the child divides it by three and identifies result (twelve, pieces, candy, divided, equally, among, three, how many).
	38	given a set of four number choices, the child can identify how many hundreds are in a thousand (how many, hundreds, thousand).
	39	given a set of four number choices, the child can identify how many threes are in eighteen (how many, threes, eighteen).
	52	given a two digit dollar value, the child can divide a single digit number and identify result (eight, earned, ninety-six, dollars, altogether, divided, money, equally, among, themselves, how much, each, share).

Table 4

Behavioral Activities Within Applications (3) Subsection of PIAT Mathematics Subtest

Subgroup	PIAT Item #	Behavioral Activity
3.1 Fractions	13	given a set of four circles divided in various proportions, the child can identify the one that is cut in half (circles, cut in half).
	20	given a set of four circles divided in various proportions, the child can identify the one that is divided into fifths (circles, divided, fifths).
	47	given a problem involving fractions and requiring one conversion, the child solves for the difference (served, one-quarter, pie, lunch, one-half, dinner, how much, is left).
	55	given a set of fractions, the child can put each in its lowest terms and identify the non-equivalent one (fraction, not equal, exactly, one-third).
3.2 Numerical Relationships	37	given a set of two digit numbers, the child can identify what number belongs between 15 and 20 in a multiple by 5 number sequence (series, numbers, left out, missing).
	44	given four equations with zero as a factor, the child can identify the one which when solved would be true (statements, correct).
	48	given a set of four digit numbers, the child identifies the ten's place (numbers, digit, 8, ten's place).
	51	given a set of numbers, the child can identify the thousands and tens place (numbers, equals, 18, thousands, 6, tens).
	54	given two two-digit numbers differentiated by numbers in the tens and ones place, the child adds the two digit numbers and identifies the result or multiplies each set, adds and identifies the result (number, stands for, sum, statements, 7, tens, ones, 5).
	60	given a picture representing gallons and tenths of gallons, the child can add one tenth and identify the result (gasoline pump, registers, gallons, tenths, pumped out).
	62	given an equation, the child can multiply a single digit number by a different power of ten, add each product, and identify the result (number, represented, expression).
	65	given a multiplication problem, the child can drop two zeros from the multiplier and identify the product as a fraction of the original product (effect, product, dropping, two zeros, multiplier, statement, as great, the same, times).
	72	given a set of factored expressions, the child can identify the complex operation expression that is not equal to 596 times 5 (expression, not equal, 596, times, 5).

Subgroup	PIAT Item #	Behavioral Activity
3.3 Word Problems	45	given a specific time, the child can add more time and identify result (started, work, eight o'clock, morning, seven and one-half hours, no, breaks, lunch, rest, time, start).
	49	given four numerical choices, the child can identify the sum of a problem involving the conversion of pints and quarts (bought, quart, milk, pint, how many, altogether).
	50	given two equations involving money values, the child can find the missing factor that makes both equations equal (bought, 12, cans, juice, dollar, how many, each, quarter, spent).
	58	given the price of a dozen objects, the child can identify the price of 36 of the objects (eggs, 60, cents, dozen, how much, 36, cost).
	59	given the concept of one yard, the child can subtract a fraction of it (1/3) and identify how many inches are left (woman, one yard, ribbon, one-third, how many, inches, were left).
	61	given three elements of a fractional equality, the child finds the missing element (each, number, trays, fruit, 9, pears, 3, apples, 18, altogether, how many, all).
	63	beginning with a single digit number, the child can identify the number which would end a sequence involving addition of each consecutive number beginning with one and ending with five (tree, 4, inches, tall, planted, one year, 5, two years, 7, three years, 10, four years, 14, how many, after, five years).
	66	given an amount of money, the child completes a percentage of the amount (25%), subtracts that product and identifies result (man, earned, $60.00, per, week, 25, percent, withheld, taxes, how much, money, take, home, $35.00, $45.00, $48.00, $25.00).
	78	given a number containing a decimal value (1.12), the child can change that value to a percentage and identify it from four choices (present, salary, previous, year, percent, former).
3.4 Geometry	56	given a circle with various parts indicated, the child can identify the radius (letter, identifies, radius, circle).
	64	given a description of a type of triangle and four written choices, the child can identify an isosceles triangle (triangle, two, three, sides, equal, length, type, equilateral, obtuse, isosceles, acute).
	68	given a description of a five or more sided figure and four written choices, the child can identify a polygon (two-dimensional figure, five, more, sides, ellipse, rhombus, quadrilateral, polygon).
	73	given the diameter of a circle, the child can identify its approximate area in square inches (diameter, circle, 14, inches, approximate, area, square inches).
	74	given four choices, the child can identify the sum of all three internal angles of an obtuse triangle (sum, all, three, internal angles, obtuse triangle).
	76	given the measurements of the sides of the right angle in a right-angled triangle, the child can identify the area of the triangle in square inches (two sides, either, right angle, right-angled triangle, 3, inches, 4, area, square inches).
	79	given four choices, the child can identify how many degrees the hour hand of a clock rotates in three hours (three hours, how many, hour hand, clock, rotate).
	81	given four formulas choices, the child can identify the formula for area of the complete outside surface of a cylinder (formula, area, complete, outside, surface, cylinder).
	84	given a triangle and the measurements of each side, the child can identify the sine of an angle in the triangle (sine, angle, triangle).

Table 4 (continued)

Subgroup	PIAT Item #	Behavioral Activity
3.0 Algebra	67	given an algebraic equation involving an unknown number and its square, the child can identify the factors of the expression (factors, expression).
	70	given an unknown number (variable), the child can divide its fifth power by its second power and identify the result (term, represented, ratio).
	71	given four choices, the child can identify the cube root of an expression (cube root, expression).
	75	given two numbers involving square roots, the child can add and identify result (sum).
	77	given two algebraic equations (involving two variables), the child can identify two missing variables in an algebrain equation that equal each other and can identify one of the two variables (true, equal).
	80	given four two variable equations, the child can solve them to identify the equation where X decreases in value when Y decreases in value (equation, decreases, value).
	82	given four choices, the child can identify an equation that, when graphed, would pass through the origin (equations, graphed, pass, through, origin).
	83	given four number choices, the child can identify the factorial of a single digit number (value, 4, factorial).

Table 5

Error Analysis Matrix for Subsections and Subgroups Within PIAT Mathematics Subtest

1. Foundations	
1.1 Number Discrimination	-1-2-3-4-12-15-17-25-33-
1.2 Size Discrimination	-5-6-
1.3 Shape Discrimination	-11-22-41-
1.4 General Information	-19-21-28-35-40-53-69-
2. Basic Facts	
2.1 Addition	-7-9-10-23-26-
2.2 Subtraction	-8-14-24-27-
2.3 Money	-16-18-29-42-43-
2.4 Multiplication	-30-34-36-46-
2.5 Division	-31-32-38-39-52-
3. Applications	
3.1 Fractions	-13-20-47-56-
3.2 Numerical Relationships	-37-44-48-51-54-60-62-65-72-
3.3 Word Problems	-45-49-50-58-59-61-63-66-78-
3.4 Geometry	-56-57-64-68-73-74-76-79-81-84-
3.5 Algebra	-67-70-71-75-77-80-82-83-

Summary

Foundations	Basic Facts	Applications
/ = % correct	/ = % correct	/ = % correct
/ = % incorrect	/ = % incorrect	/ = % incorrect

Table 6

Example of Error Analysis Matrix Application

1.	Foundations		
1.1	Number Discrimination	-1-2-3-4-12-15-17-25-33-	100%[a]
1.2	Size Discrimination	-5-6-	
1.3	Shape Discrimination	-11-22-41-	100%
1.4	General Information	-19-21-28-~~35~~-40-53-69-	67%
2.	Basic Facts		
2.1	Addition	-7-9-10-23-26-	
2.2	Subtraction	-8-14-24-27-	
2.3	Money	-16-18-29-~~42~~-43-	50%
2.4	Multiplication	-30-34-36-~~46~~-	75%
2.5	Division	-31-32-~~38~~-39-52-	80%
3.	Applications		
3.1	Fractions	-13-20-~~47~~-~~55~~-	0%
3.2	Numerical Relationships	-37-44-48-~~51~~-~~54~~-60-62-65-72-	60%
3.3	Word Problems	-45-~~49~~-50-~~58~~-59-61-63-66-78-	50%
3.4	Geometry	-~~56~~-~~57~~-64-68-73-74-76-79-81-84-	0%
3.5	Algebra	-67-70-71-75-77-80-82-83-	

Summary

Foundations	Basic Facts	Applications
$\frac{4}{5}$ = 80% correct	$\frac{8}{11}$ = 73% correct	$\frac{5}{13}$ = 38% correct
$\frac{1}{5}$ = 20% incorrect	$\frac{3}{11}$ = 27% incorrect	$\frac{8}{13}$ = 62% incorrect

[a] % correct within subgroup

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* As part of its continuation proposal, the Institute was required to prepare these monographs. Because they are part of the proposal, they are not available for general distribution.